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First named inventor: Lawrence E. Pado
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Examiner: Joseph P. Hirl

Title: **NEURAL NETWORK PREDICTIVE CONTROL COST FUNCTION DESIGNER**

Commissioner for Patents
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PROPOSED RESPONSE TO FINAL OFFICE ACTION DATED MAY 2, 2008

This response includes a section for amendments to the claims and a section for remarks.

Respectfully submitted,

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AMENDMENTS TO THE CLAIMS

Claims 1-14 (Cancelled)

15. (Currently amended) The method of Claim [[14]] 73, wherein the cost function parameters selected include [[the]] position gain and [[the]] velocity gain.

16. (Original) The method of Claim 15, wherein the position gain selected includes one of 0 and 1 and the velocity gain selected includes one of 0 and 1.

Claims 17-19 (Cancelled)

20. (Currently amended) The method of Claim [[19]] 73, wherein combinations of the cost function parameters, the input weight, and the predicted future states are considered stable if the sum of the control system phase differential and operational plant phase differential is either between +150 and +180 degrees or between -150 and -1 80 degrees, wherein the control system phase differential is the phase differential between a control input and a control output, and wherein the operational plant phase differential is the phase differential between the plant input and the plant output.

21. (Currently amended) The method of Claim [[19]] 73, wherein more stable combinations of the cost function parameters, the input weight, and the predicted future states are those for which the sum of the control system phase and the known plant phase is closest to 180 degrees or negative 180 degrees and less stable combinations of the cost function parameters, the input weight, and the predicted future states are those for which the sum of the control system phase and the known plant phase is closest to 0 degrees.

Claims 23-72 (Cancelled)

73. (New) A method of designing a predictive control system for a dynamic nonlinear plant, the control including a neural network for predicting a state of the plant and a cost function for generating a cost function response u(n) for the plant, the cost function response u(n) generated from parameters including a predicted state by the neural network, the method comprising:

sensing responses of the plant to an input signal that operates the plant at different frequencies;

taking the plant off-line; and

testing different permutations of cost function parameters to determine a viable permutation for the cost function, wherein testing each permutation includes

supplying the input signal to the neural network, and

comparing phases of the cost function responses u(n) to phases of the previously sensed plant responses at corresponding frequencies.

74. (New) The method of claim 73, wherein the input signal is chirped only once for the plant; and wherein the input signal to the neural network is chirped once for each permutation of cost function parameters.

75. (New) The method of claim 74, wherein the chirped input to the plant and the corresponding plant responses are also used to train the neural network.

76. (New) The method of claim 74, wherein the different permutations produce different cost function responses u(n) and wherein the phase of the cost function response u(n) to the chirped input is calculated; and wherein the plant phase is compared to the phases of all of the different cost function responses u(n).

77. (New) The method of claim 73, wherein only permutations at resonant frequencies are tested for stability.

78. (New) The method of claim 73, wherein phase of the plant response and the phase of the cost function response u(n) are in the stable regions shown in Figure 4B.

79. (New) The method of claim 73, wherein AB looping is used to test different permutations of the cost function parameters.

80. (New) The method of claim 73, wherein forget factor looping is used to test different permutations of the cost function parameters.

81. (New) An article for tuning a cost function of a neural predictive control system for a plant, the system including a neural network for providing a predictive state to the cost function in r the article comprising computer memory encoded with instructions for causing a computer to test different permutations of cost function parameters to determine a viable permutation for the cost function, each permutation resulting in a cost function response u(n), the testing of each permutation including:

    supplying a chirped input to the neural network, the chirped input to the neural network corresponding to resonant frequencies of the plant; and

    accessing recorded responses of the plant to its resonant frequcies; and comparing phases of the cost function response u(n) to phases of the plant response.

82. (New) A system comprising:

a plant; and

a predictive control system for the plant, the system comprising at least one processor programmed with a neural network, a cost function for providing a control response to a state provided by the neural network, and code for tuning the cost function, the code causing the at least one processor to record responses of the plant to a chirped input; take the plant off-line; and test different permutations of cost function parameters to determine a viable permutation for the cost function, wherein testing each permutation includes:

supplying a chirped input to the neural network, the chirped input to the neural network being at the same frequencies as the chirped input to the plant, and

comparing phases of the cost function response u(n) to phases of the previously measured plant responses.

REMARKS

Claims 1-72 are pending.

Claims 1-72 are rejected.

In the office action dated May 2, 2008, claims 1-72 are rejected under 35 USC §102(b) as being unpatentable over Pado U.S. Patent No. 6,185,470. The rejection has been rendered moot the amendments above. Claims 73-82 are new, claims 1-14, 17-19 and 23-72 have been cancelled, and claims 15-16 and 20-21 have been amended to depend from new claim 73. Claims 15-16, 20-21 and 73-82 are believed to be allowable over the '470 patent.

The '470 patent discloses a neural predictive control system for a plant. The control system includes a neural network for predicting a state of the plant and a cost function for generating a control signal for controlling the plant. The cost function generates the control signal from parameters including the state predicted by the neural network.

During design of the control system in the '470 patent, the plant is used to generate training data for the neural network. The training data includes responses of the plant to different values of the control signal. As but one example, the plant may be an aircraft component having a control surface (e.g., a wing having an aileron). The control surface is moved in response to a control signal u(n) and a sensor on the component measures position and velocity. The sensor provides feedback y(n) about the component's state in response to the control signal u(n).

The neural network in the '470 patent is trained on the training data so it can predict the state of the plant in response to different values of the control signal. According to col. 5, lines 17-25 of the '470 patent, the training includes comparing

predicted output $y_p(n)$ to actual (sensed) output y(n) of the plant. Thus, the plant is used to train the neural network.

The performance index receives a reference trajectory $y_d(n)$. The reference trajectory $y_d(n)$ represents a desired future output of the plant. The performance index is a cost function for "evaluating the predicted performance of the trial input value to achieve the desired reference trajectory" (col. 5, lines 30-33). An example of a cost function is provided at col. 5, line 44. For example, a reference trajectory of $y_d = 0$ might mean that full wing flutter (vibration) suppression is desired. The performance index will determine whether the control signal will meet that desired output. Different trial values are evaluated, and the trial value having the lowest cost is selected.

This example of the cost function has several cost function parameters, which have to be determined during design. During design, it is desirable to test the control system for different values of the parameters.

According to col. 6, lines 17-24, different permutations of cost function parameters (the "control horizon") are presented to the neural network, and one of the permutations is selected. This is one way of tuning the control function is tuned. Figure 1 and col. 6, lines 32+ of the '470 patent suggests that the plant is used to provide feedback while the tuning is being performed.

However, using the plant to tune the cost function has certain drawbacks. These drawbacks include manually tuning of the control system, and risking possible damage to the plant.

Manual tuning of the control system is very time consuming and labor intensive. The manual tuning described in the '470 patent is labor intensive because the plant is controlled and its responses are measured for each permutation of cost function parameters. There could be thousands of permutations, taking hours or even days to evaluate.

The method of claim 1 overcomes these drawbacks. The method of claim 1 includes measuring the response of a plant to a single input signal. Then, the plant is taken off line, and the signal is supplied to the neural network based control system. Phases of the previously measured responses of the plant (measured while it was still on-line) to the input are compared to a phases of control responses u(n) at corresponding frequencies.

In the method of the '470 patent, the plant is controlled and its responses measured for each permutation of cost function parameters. In the method of claim 1, the plant is controlled and its responses may be measured only once. A processor compares the recorded plant data to each of thousands of different permutations to find the "best" one. The processor could make each comparison for each permutation in one second or less. In this manner, the method of claim 1 greatly reduces time and cost of tuning the cost function.

Moreover, the method of claim 73 does not subject the plant to permutations that could damage the plant. The plant is off-line while the permutations are being tested.

Thus, the '470 patent does not teach or suggest the method of base claim 73. Therefore, base claim_73 and its dependent claims 15-16, 20-21 and 73-80 should be allowed over the '470 patent. Base claims 81 and 82 should be allowed for the same reasons.

QUESTION FOR EXAMINER HIRL: THE OFFICE ACTION IS FINAL, EVEN THOUGH WE JUST FILED AN RCE. WOULD YOU ENTER THE PROPOSED AMENDMENTS ABOVE, OR WOULD YOU REQUIRE ANOTHER RCE?